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A REMOTE, UNMANNED DEWATERING SYSTEM FOR RECOVERY OF THE SOLID --ETC(U)

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Technical Report 144

A REMOTE, UNMANNED DEWATERING SYSTEM FOR RECOVERY OF THE SOLID ROCKET BOOSTERS OF THE SPACE SHUTTLE PROGRAM

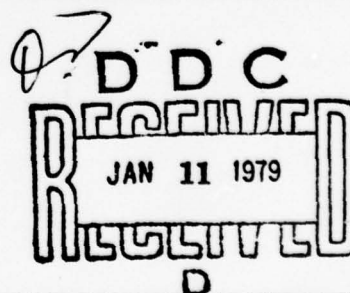
AJ Schlosser
1 August 1977

Research and Development Report: August 1975 — June 1977

Prepared For
National Aeronautics and Space Administration

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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ADMINISTRATIVE INFORMATION

This report covers work performed during the period August 1975 through June 1977. The National Aeronautics and Space Administration provided funds used by the Applied Technology Division, NOSC, to develop and test the systems described herein. Work was performed under NASA Defense Purchase Request CC 54247A.

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A. J. SCHLOSSER, Head
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21. ABSTRACT (Continue on reverse side if necessary and identify by block number) The design, fabrication, and testing of a prototype system for dewatering the Solid Rocket Boosters recovered after launch of the NASA Space Shuttle Vehicle are described. A summary of operations conducted with unmanned underwater recovery vehicles (the CURV) provides the background for the development of the design concepts embodied in the dewatering system.		

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SUMMARY

This report presents a summary of past CURV III operations, such as environmental surveys at the Farallon Islands, recovery of the Radioisotopic Thermoelectric Generator from the San Juan Seamount, and the survey of the ore ship EDMUND J. FITZGERALD, sunk in Lake Superior. This experience in utilizing an unmanned, remote work system provided the background and expertise to propose and successfully build an unmanned system for the John F. Kennedy Space Center in support of retrieving the Solid Rocket Boosters used to launch the Space Shuttle Vehicle.

The dewatering system mission is to dewater a spent Solid Rocket Booster (SRB) casing (12 ft in diameter by approximately 130 ft long), which floats nearly in the vertical after impact so that it re-orientes to the horizontal and may be towed to port for refurbishment and reuse.

The paper describes the design, fabrication and testing of the prototype system.

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BACKGROUND

The CURV family of vehicles gained acceptance as a diversified work tool with the recovery of the H-Bomb off Palomares, Spain, in April, 1966. From that time the remotely controlled unmanned vehicles came into the operational community of ocean search and recovery.

The ability to perform useful work in the oceans has been demonstrated by the Cable-controlled Underwater Vehicle (CURV III) (Ref. 1). CURV III (Fig. 1), originally conceived as a search and recovery vehicle for lost underwater ordnance, has evolved into a multi-purpose tool with expanded capabilities for search, recovery, test, and investigation. Today, the ocean floor to depths of 7,000 ft is home to CURV III in many varied work tasks, i.e., bottom sampling, photographic and television recording, and using the work arm in manipulating attachment devices for recovery of equipment within the water column or on the sea floor.

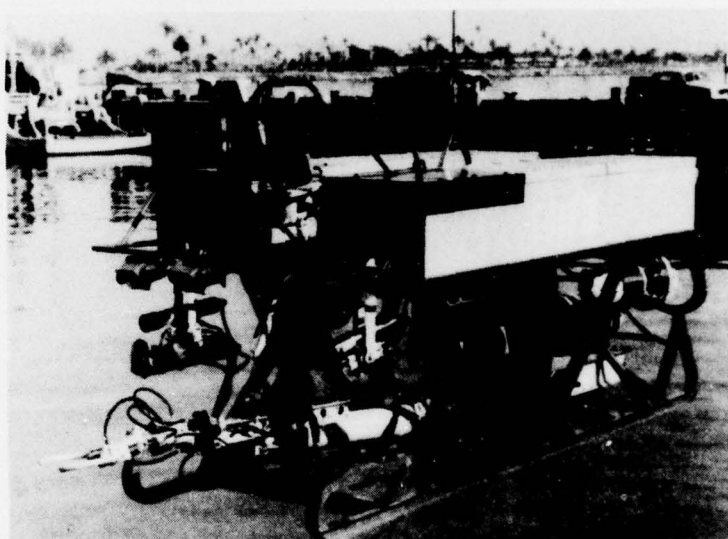


Figure 1. CURV III.

The ocean disposal of radioactive wastes began in 1946 in the area of the Farallon Islands. Using its photographic and core-sampling systems, CURV III was used to survey (Ref. 2) the disposal canisters in 1974 and 1975 (Fig. 2). This task was conducted for the Office of Radiation Programs of the Environmental Protection Agency (EPA). Eight dives were accomplished, with a total bottom time of over 55 hours. Several core samples and a 35 mm photographic record of core locations and orientation were obtained. Survey of the

entire site was made possible by CURV III's ability to sustain long-duration dives without concern for life support requirements.

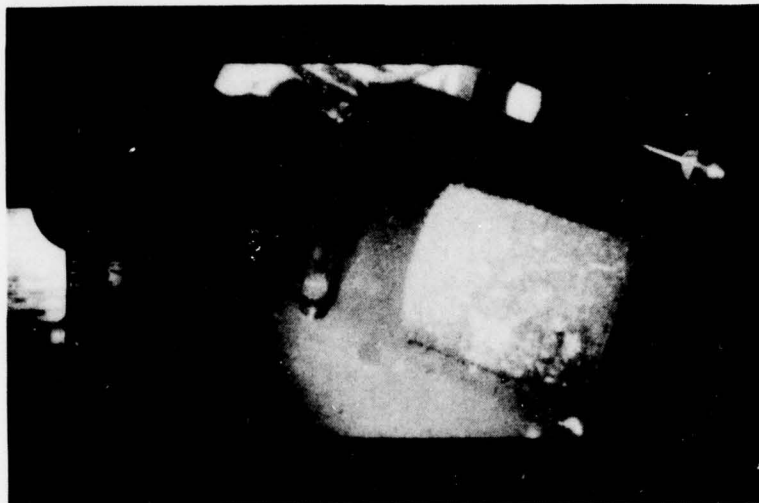


Figure 2. CURV III core-sampling device.

The survey of the ore ship EDMUND J. FITZGERALD, lost in Lake Superior, provided another unique opportunity for CURV III and its combined photo/TV system. The U.S. Coast Guard, in investigating the probable cause of sinking, tasked CURV III to survey, identify (photographic and video tape) the bottom wreckage. CURV III surveyed the wreckage, identified by photo/TV the wreck, and examined the areas of interest – hatch covers and hatches. A full survey was accomplished with a total dive time of 56 hours (12 dives). All data acquired was transferred to the Coast Guard Review Board. Findings were released by the Coast Guard on 3 August 1977, and the ship identity, using CURV III TV coverage, was shown by NBC Television news.

As reported in Ref. 3, CURV III, through the photo/optical system supplemented by the manipulator, provided the work tool to recover a radioisotopic thermoelectric generator (Fig. 3) from the San Juan Seamount at a depth of 762 m (2,500 ft). Recovery had been attempted twice previously without success. The seamount had been the site of numerous surveys, and the area was congested with abandoned bathothermygraph wire and numerous large rocks on the seamount surface. The survey revealed that the RTG was located near the edge of the seamount. Should the line break during retrieval, the RTG would fall to the sea floor, a depth of 3,636 m (12,000 ft). Successful recovery was accomplished by using the CURVE manipulator to attach a line. A vessel on the surface provided the lift.



Figure 3. Radioisotopic thermoelectric generator.

INTRODUCTION

The Naval Ocean Systems Center (NOSC) was approached by the National Aeronautics and Space Administration (NASA), John F. Kennedy Space Center, with the SRB recovery problem. The Space Shuttle is launched by means of the two Solid Rocket Boosters to achieve lift-off and initial trajectory into orbit. Once the fuel is spent the SRBs are jettisoned and fall by parachute into the ocean. After impact, the SRBs assume a "spar" mode and are available for recovery (Fig. 4). The recovery is achieved by having the SRB attain a "log" mode to allow it to be towed to port for refurbishment.

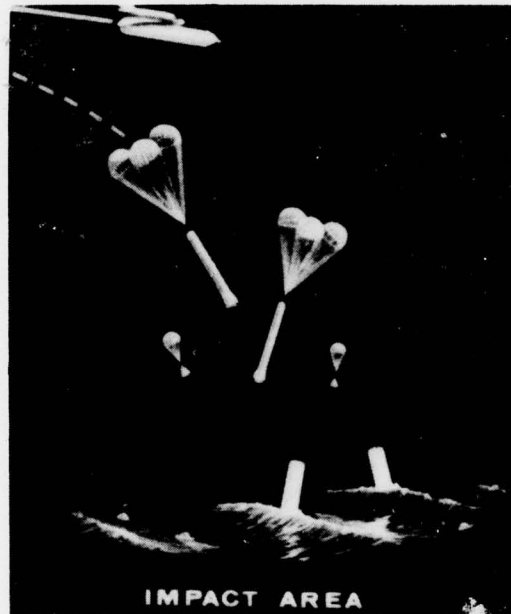


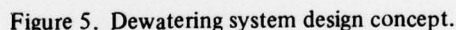
Figure 4. Artist's conception of SRB descent and landing in spar mode.

As stated by NASA, the SRB recovery system mission requirements are:

1. Both day and night operation
2. Operation in sea conditions up to and including sea-state 4
3. Operations up to 300 ft away from the recovery vessel (horizontal range) and to depths of 175 ft
4. Operations in currents of 6 knots or less
5. Dewatering the SRB in a maximum of 3 hours
6. Withstanding all forces imposed by towing the SRB at a speed of 10 knots

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Control Console
Umbilical Cables
Nozzle Plug (NP)
Umbilical Storage Basket
NP Handling Subsystem
Auxiliary Support Subsystem



The SRB dewatering system and its associated equipment is installed aboard a recovery vessel for transportation to the splash-down site. After arrival at the SRB impact area, a search is conducted to gain contact with the SRB. Once established, the NP is launched (Fig. 6) and navigated to the SRB. The SRB is inspected below the surface with the NP's onboard TV camera. Upon completion of the inspection, the NP is maneuvered below the SRB and then docked in the nozzle. The NP locking arms are then deployed to hold it in place, and the dewatering is begun.

Dewatering is accomplished in two stages: SRB in “spar” mode, and SRB in “log” mode. During spar mode dewatering, compressed air supplied from the recovery vessel through a pneumatic umbilical is used to force water past the NP and into the casing until the vertical SRB becomes unstable and assumes the log mode. At this time the inflatable bag on the NP is inflated and the dewatering hose is deployed. Compressed air is again pumped

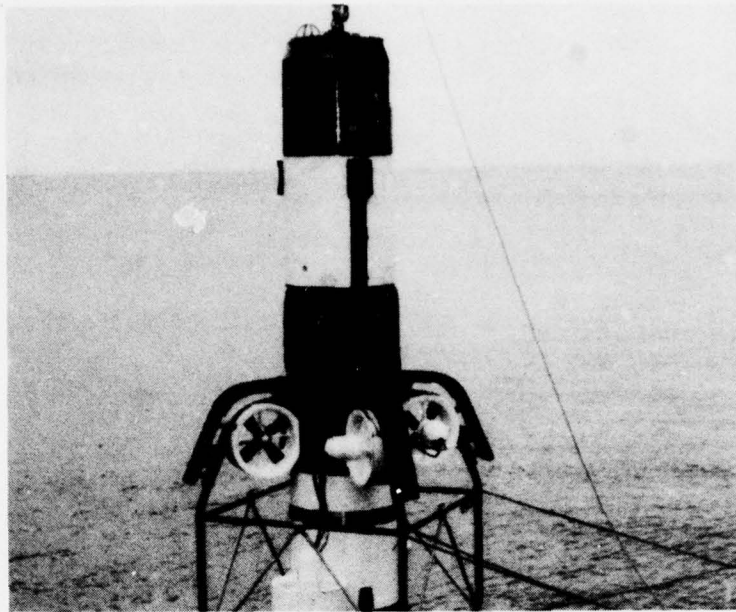


Figure 6. Nozzle plug.

through the NP into the SRB until a ΔP is attained (10 psi maximum) which forces the remainder of the water out past the seal and through the NP dewatering hose. After completion of dewatering, the umbilicals are disconnected, and the SRB, with the NP providing the seal to the nozzle, is towed to port.

DESIGN AND FABRICATION

The design concept of the solid rocket booster dewatering system (Ref. 4) was to utilize existing technology and off-the-shelf hardware components wherever practical. The entire system was subjected to NOSC design reviews, as well as Kennedy Space Center 30, 60, and 90 percent design reviews. Additionally, a complete hazard analysis was conducted, and a failure modes and effects analysis (FMEA) was maintained throughout the design and testing.

Control Console

The control console (Fig. 7) provides the system operator with a video display, NP status information, and all necessary controls to maneuver the NP during transit from the recovery vessel to the SRB. The remote control unit has vertical and horizontal thruster controls. All components have been designed to withstand shock and vibration for shipboard usage. Displays and operating controls were human-engineered to provide single-operator control. Visual displays present such information as electrical voltages and hydraulic pressures, NP depth, and NP water leak detection. Lights indicate NP contact and arm lock, and there is a three-digit display with an LED array to show compass headings. Functional controls

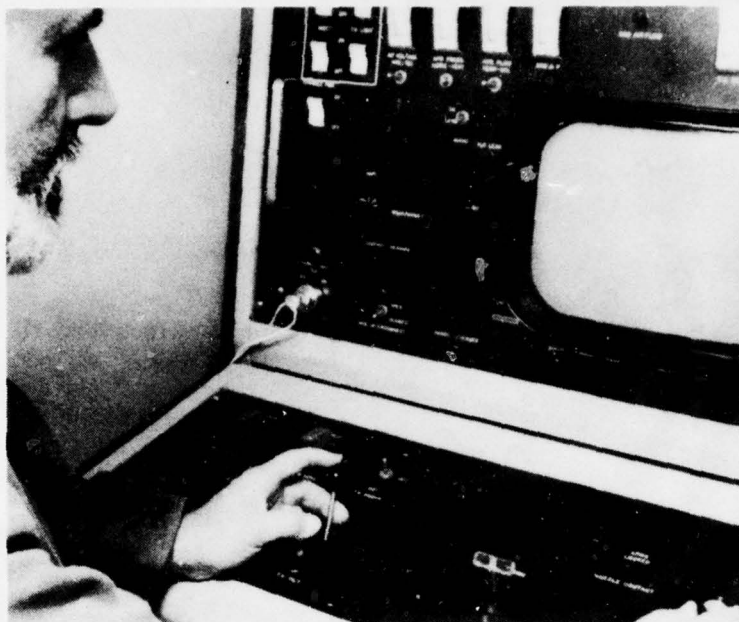


Figure 7. Control console.

consist of horizontal and vertical thruster control, TV focus and tilt, arm deployment switch, air deployment, dewatering hose deployment, and power controls.

Umbilical Cable

The umbilical cable provides the physical, electrical and pneumatic connection between the shipboard components of the dewatering system and the NP. The physical connection provides a 10,000-lb break strength link (Kevlar) between the recovery vessel and the NP as an integral part of the electrical cable. The electrical cable supplies power to the NP and carries control signals. The pneumatic hose supplies compressed air to the NP for dewatering the SRB and inflating the air bag for sealing. The electrical cable and pneumatic hose are married at 3-ft intervals with nylon rope to form a single umbilical. Floats are located on the umbilical at intervals varying from 10 to 15 ft.

Nozzle Plug

The NP is designed to maneuver for inspection of the in-water portion of the SRB and docking in its nozzle. The NP provides the mechanical means for dewatering the SRB. The general characteristics of the NP are:

Design Depth	175 ft
Working Depth	115 ft
Height	14 ft
Outside Diameter	7 ft

Weight in Air	3,400 lb
Buoyancy (No Ballast)	+ 265 lb
Speed: (Horizontal)	3.4 ft/sec
(Vertical)	4.2 ft/sec

The NP was designed with a modular approach for ease of fabrication and maintenance (Fig. 8). The six modules are described below.

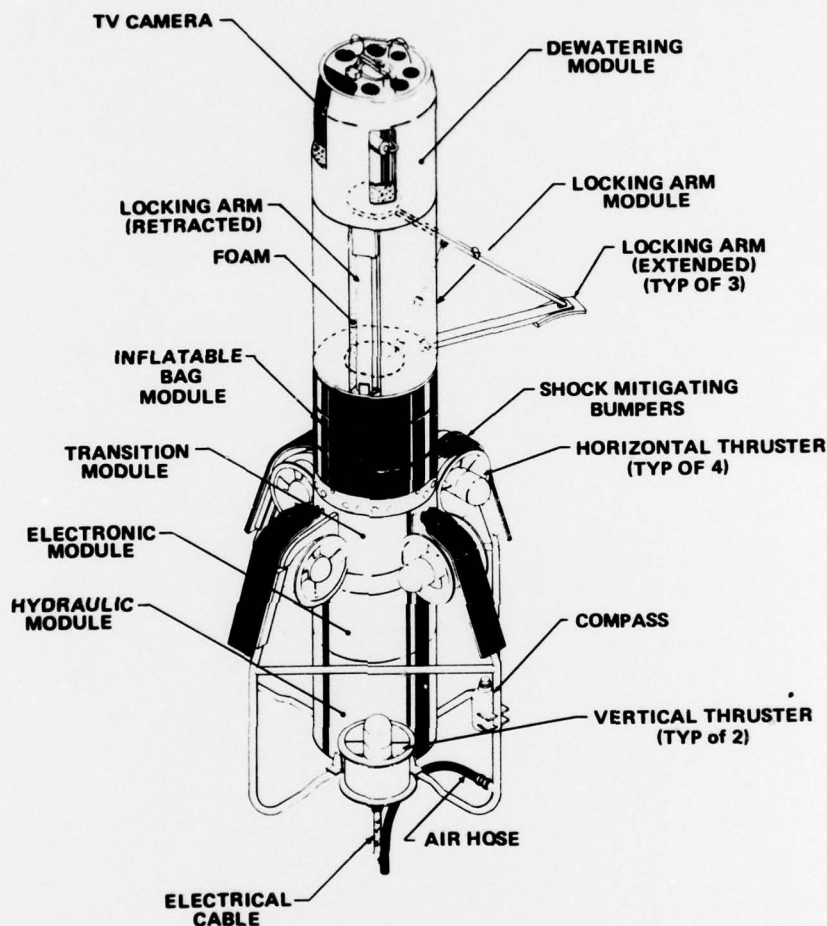


Figure 8. Modular structure of nozzle plug.

- **Hydraulic Module.** The hydraulic module houses two 15-HP electro/hydraulic pumps. These units provide the power to the four vertical and two horizontal thrusters and the locking arms. The hydraulic system operates at 3,000 psi.
- **Transition Module.** The transition module provides the transfer interface for all pneumatic, electrical and hydraulic functions. It is the structural portion of the NP and has the thrusters and shock-mitigating bumpers mounted on it. The bumpers

provide the means to seat the NP in the nozzle of the SRB prior to deployment of the locking arms. Each bumper has a proximity switch and provides a signal displayed as a light on the control console as the NP becomes firmly seated in the SRB nozzle. The framework provides the conduit for the electrical power and the air supply from the ship.

- Electrical Module. The electrical module houses all the NP control functions such as: signal control relays, thruster controls, and sensors.
- Inflatable Bag Mandrel Module. The inflatable bag mandrel module holds the inflatable bag used to seal the nozzle of the SRB during second-stage dewatering (Log Mode). The bag is designed to inflate from 30 in. diameter to 56 in. diameter to seal the nozzle. The design is based upon the Goodrich space saver tire concept. The mandrel also houses the dewatering pipe and syntatic foam for flotation.
- Locking Arm Module. The locking arm module provides the NP with the means to secure itself firmly to the nozzle once docking has been assured. The locking arms are deployed by individual piston/cylinder arrangements. An over-center design is used to assure locking in the event of hydraulic failure. Syntatic foam is fitted around this section to provide buoyancy.
- Dewatering Module. The dewatering module contains the dewatering hose, the TV camera and lights, and the search and recovery system (SAR). Buoyancy is also provided through syntatic foam. The dewatering hose is used to channel the water out of the SRB when log mode has been attained. The hose is wire-helixed rubber stowed in the central cylinder of the module. A spring-loaded arrangement is used to deploy the hose. The TV camera is mounted to provide video displays on the monitor. The lights have half-power and full-power operational capabilities. SAR equipment includes a pinger, strobe light, and lifting eyes.

Handling Subsystem

The handling subsystem provides storage and launch equipment for the NP and the umbilical cable, and special equipments for removing the NP from the SRB on land.

TEST PLAN

An integrated test plan (ITP) was developed (Ref. 5) to provide assurance that all elements and subsystems comprising the dewatering system have been adequately tested and properly integrated. The ITP also assures that testing is accomplished in a safe and timely manner, is economical, and that personnel, facilities, hardware and platform requirements are compatible. Testing was accomplished in three phases:

- Phase A. Assembly and subassembly testing, includes bench test of components, sub-assemblies, etc., that do not have factory acceptance tests.
- Phase B. Integrated testing, verifies the electronic, hydraulic, mechanical and pneumatic compatibility of the assemblies and subsystems as they are integrated into the system. Included is the dockside testing to demonstrate the dynamic and structural integrity of the system in a marine environment.
- Phase C. At-sea testing to demonstrate the ability of the system to perform the mission requirements.

OCEAN TEST FIXTURE

At-sea testing requires a demonstration of the dewatering system's ability to perform to the mission requirements. An ocean test fixture (OTF) was designed and fabricated to demonstrate the compatibility of the system. The OTF is a cylindrical tank with a hemispherical cap on one end, and a full-scale mock-up of an SRB nozzle on the other end. The diameter of the OTF is 12 ft, and the length is 37 ft. Wall thickness of the OTF is 0.5 in. The nozzle is constructed of fiberglass; the skirt frame is of pipe (Fig. 9). This configuration represents the aft segment of an SRB.

AT-SEA TESTING

The Phase C at-sea tests of the prototype system were conducted at the Naval Ocean Systems Center test range at Wilson Cove, San Clemente Island, California, in June 1977. Testing was conducted in an area having a water depth of 110 ft, except for the maximum design depth and maximum vertical velocity tests, which were conducted in water of 200 ft depth.

The at-sea tests were conducted with the test platform and OTF moored as shown in Fig. 10. The system tests conducted and their test objectives are as follows:

- Spar Mode Testing. To demonstrate the ability of the Nozzle Plug to acquire, maneuver, dock and dewater the SRB while in a Spar Mode (Fig. 11).
- NP Maneuverability. To demonstrate the maneuverability of the NP in an operational mode. Responses include forward and aft thrust and yaw and heave characteristics.
- Depth Test. To demonstrate the NP's ability to operate at the design depth. All functions were to be exercised with the exception of sealing bag inflation.
- Inspection of SRB. To demonstrate the NP's capability to inspect the SRB casing prior to dewatering.

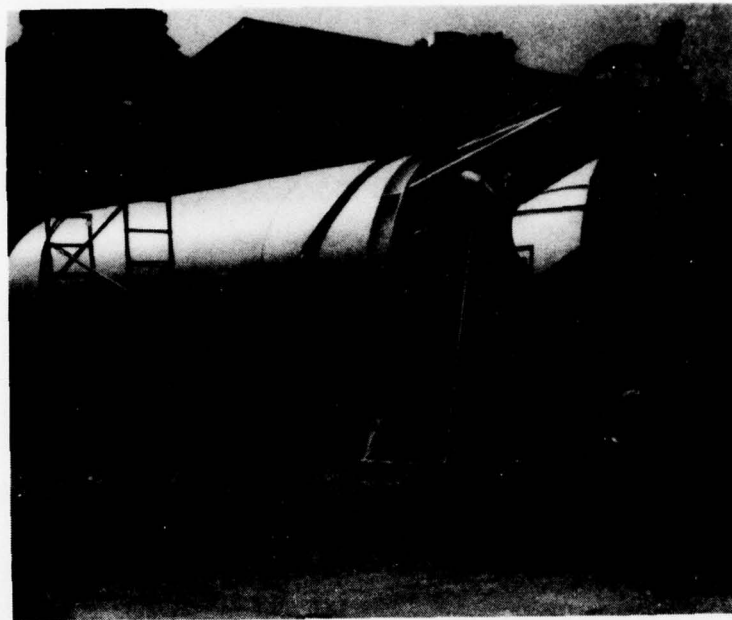


Figure 9. Ocean test fixture.

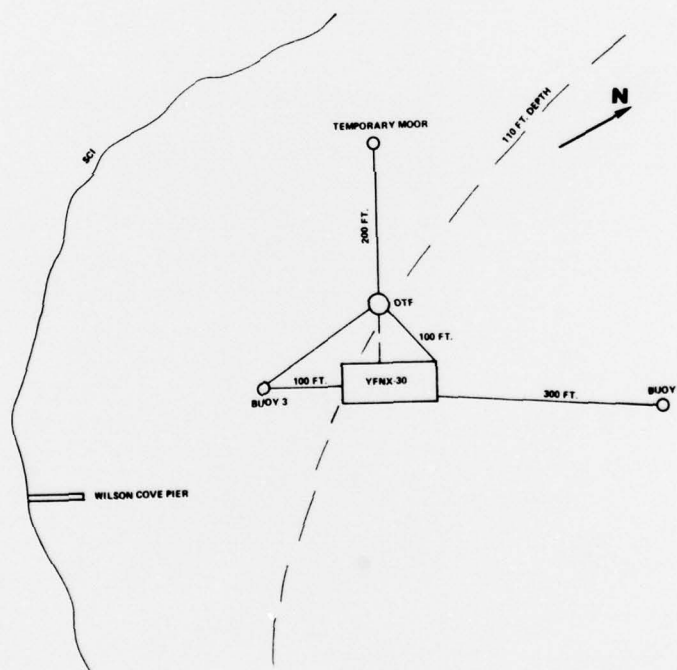


Figure 10. Moor arrangement for at-sea tests.

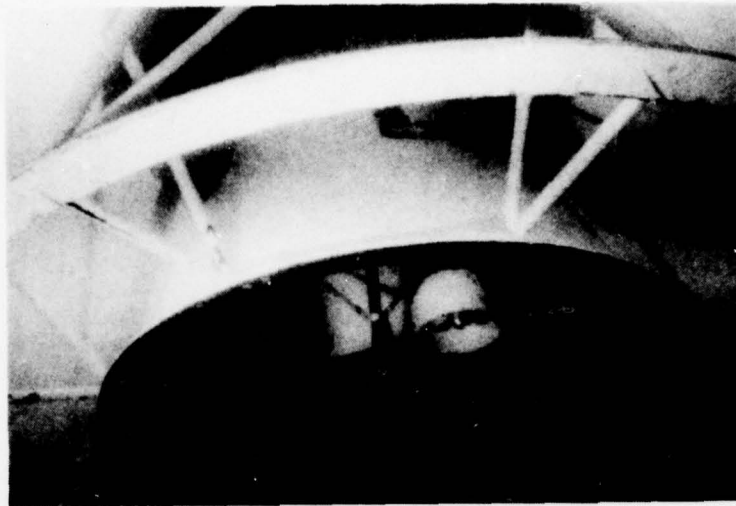


Figure 11. Spar Mode testing.

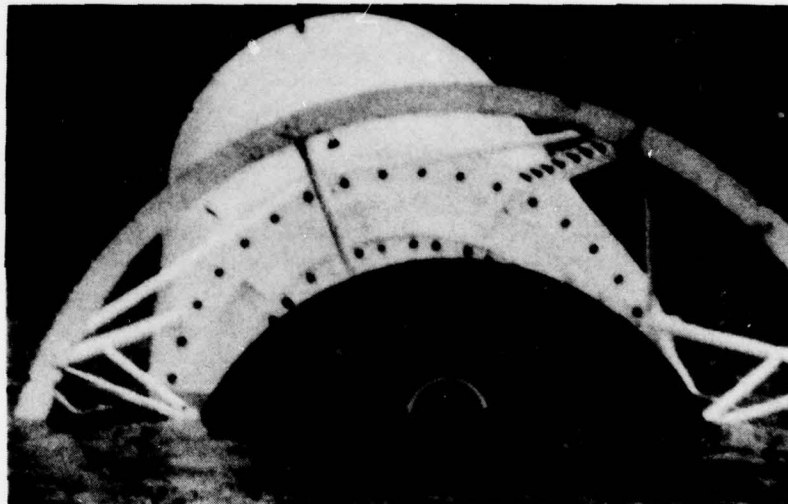


Figure 12. Log Mode dewatering.

- Docking. To demonstrate the NP's capability to dock in the nozzle of the SRB up to sea-state 4.
- Spar Mode Dewatering. To demonstrate the NP's ability to dewater in the spar mode.
- Log Mode Dewatering. To demonstrate the ability to dewater in the log mode by inflation of the sealing bag and deployment of the dewatering hose (Fig. 12).

- Undock and Redock. To demonstrate the NP's ability to withdraw from the nozzle after docking and deployment of the locking arms, then to be able to redock and secure.
- Surfacing and Retrieval. To demonstrate the NP's ability, by virtue of its inherent positive buoyancy, to surface without use of vertical thrusters, and to be retrieved.
- Emergency Retrieval. To demonstrate retrieval by use of the SAR gear and surface ship retrieval hook.

CONCLUSIONS

The prototype SRB dewatering system has successfully demonstrated the feasibility of the concept as proposed by NOSC to utilize an unmanned, remotely controlled, tethered vehicle to mate with the nozzle and dewater an expended SRB. All major goals of the program were accomplished and demonstrated by the ocean tests.

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